

**4. FRIDAY NOVEMBER 8**

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**4.1. PREDICTION OF ACID ROCK DRAINAGE:  
FROM MINE DEVELOPMENT TO CLOSURE**

**Keith Ferguson  
Placer Dome Inc.**

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# PREDICTION OF ACID ROCK DRAINAGE

*From Mine Development to Closure*



## THE ARD PREDICTION PROGRAM

- REVIEW OF GEOLOGY AND MINERALOGY DATA
- SEEPAGE QUALITY FROM ORE AND WASTE STOCKPILES
- OBSERVATIONS OF STAINING AND HEAT FROM U/G WALLS AND PILES
- 422 SAMPLES FOR ABA
- VISUAL SULPHIDE ESTIMATES
- 4 KINETIC TESTS
- 26 SAMPLES FOR METAL CONTENT

## FINDINGS OF GEOLOGY EVALUATION

- CORRELATION BETWEEN GOLD AND VISUAL PYRRHOTITE
- ROCK IS HARD AND FINE GRAINED
- PYRRHOTITE IS THE PRINCIPLE SULPHIDE
- CONTACTS BETWEEN ORE AND WASTE ARE SOMETIMES SHARP
- LITTLE CARBONATE PRESENT - PRIMARILY CARBONATE
- NO GYPSUM OR OTHER SECONDARY MINERALS
- VERY SHALLOW DEPTH OF OXIDATION
- GRAPHITE VERY RARE
- GENERALLY GOLD AND SULPHIDE FLUIDS OCCURRED TOGETHER

## FINDINGS OF SEEPAGE MONITORING

- NEUTRAL pH - 7.5
- MODERATE SULPHATE - 250 mg/L
- HIGH ALKALINITY - 230 mg/L
- LOW METALS

## FINDINGS OF STAIN INVESTIGATIONS

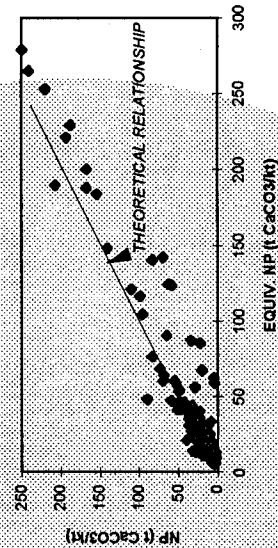
- LIMITED STAINING BUT SOME MOTTLING AROUND WATER INFLOWS U/G
- SOME STAINING IN OLDER WORKINGS BUT NONE IN RECENT
- EVIDENCE OF HEAT GENERATION FROM ORE STOCKPILE
- SOME OXIDATION PRODUCTS FOUND IN ORE STOCKPILE

## FINDINGS OF ABA MONITORING

- 71 SAMPLES OF U/G WALLS (1, 2 AND 3 m FROM OREBODY)
- 216 SAMPLES OF ORE/TAILING
- 135 SAMPLES OF WASTE ROCK

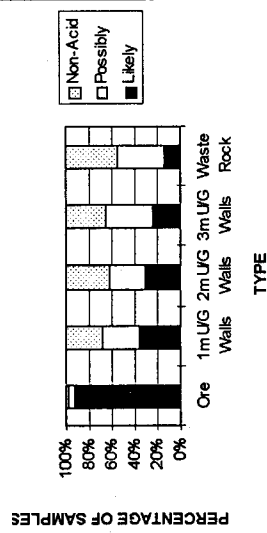
## TOTAL AND CARBONATE NP

NP VERSUS EQUIVALENT NP - ALL DATA

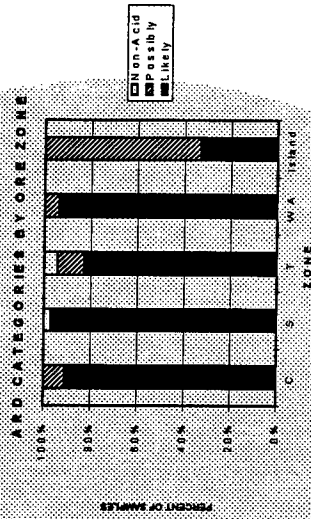


## ARD CATEGORIES

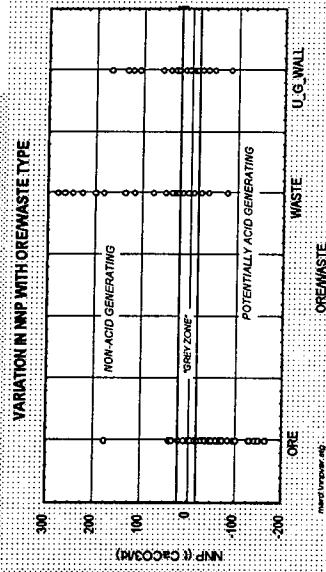
ARD CATEGORIES FOR ORE/WASTE TYPES



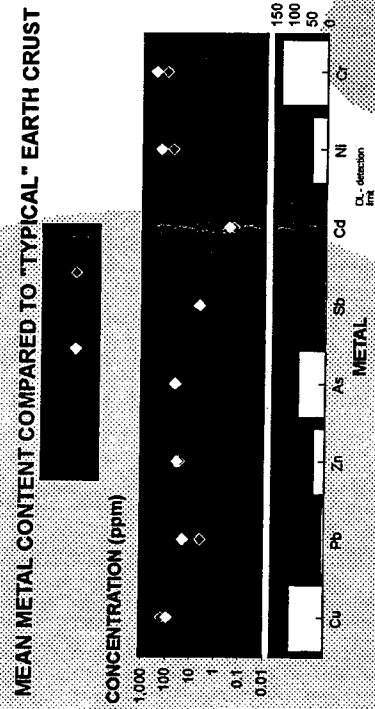
## ABA VARIATION BETWEEN ORE ZONES



## RANGE IN ABA BY ORE/WASTE TYPE



## METAL CONTENT OF ORE AND WASTE



## MUSSELWHITE ARD PREVENTION PLAN

- FLOOD TAILING IMPOUNDMENT
- MONITOR WASTE ROCK SEEPAGE AND USE WASTE ROCK UNDERGROUND
- MONITOR UNDERGROUND MINERWATER AND FLOOD AT CLOSURE

## MT. MILLIGAN ARD TEST PROGRAM

- ACID BASE ACCOUNTING
  - INITIAL TEST (67 SAMPLES)
  - OVERBURDEN TEST (42 SAMPLES)
  - SIMULATED WASTE DUMP (3 SAMPLES)
  - OUTCROP TEST PROGRAM (8 OUTCROPS)
  - DETAILED TEST PROGRAM (1600 SAMPLES)
  - TAILING TEST PROGRAM (40 SAMPLES)
  - NP INVESTIGATIONS (26 SAMPLES)

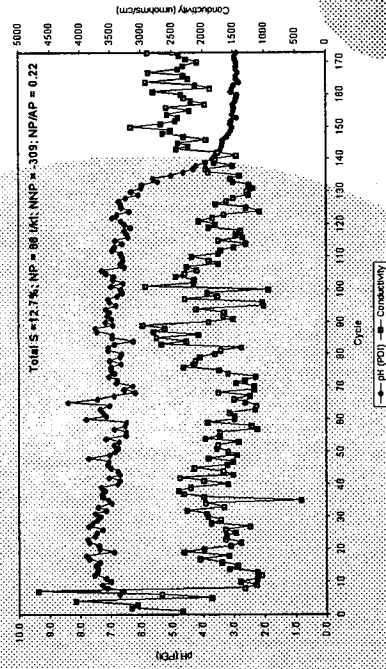
## MT. MILLIGAN ARD TEST PROGRAM

- KINETIC TEST PROGRAM
  - COLUMN EXPERIMENTS (7 TESTS)
  - ACCELERATED COLUMNS (7 TESTS)
  - SIMULATED WASTE DUMP (4 TESTS)
  - CLEANER TAILING H.C. (4 TESTS)
  - OXIDE ORE H.C. (2 TESTS)
  - WORST CASE WASTE ROCK H.C. (1 TEST)
  - LONG-TERM KINETIC TESTS (2 TESTS)

## MT. MILLIGAN ARD TEST PROGRAM

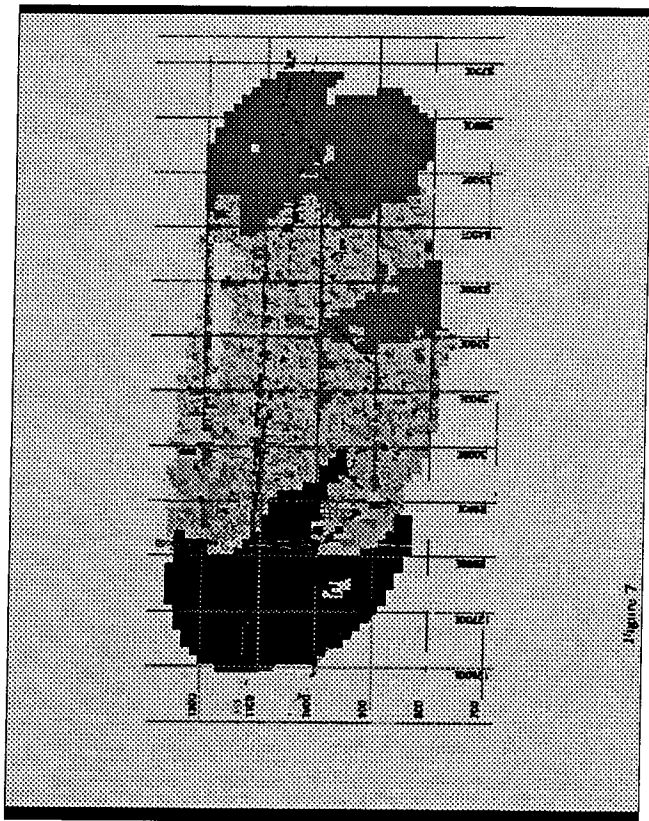
- MINERALOGY INVESTIGATIONS
  - KINETIC TEST PROGRAM
  - OUTCROP SAMPLES
  - SEM/MICROPROBE INVESTIGATIONS
  - WEATHERING SLAB EXPERIMENTS

## LONG-TERM KINETIC CELL TESTS



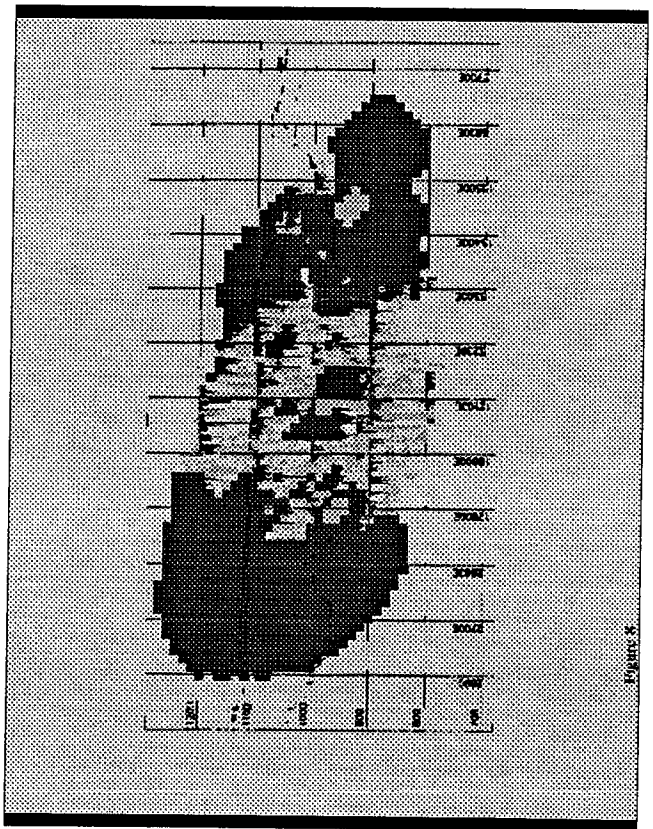
## MT. MILLIGAN ARD TEST PROGRAM

- GEOCHEMICAL MODELLING
  - PHASE I MODELLING
  - PHASE II MODELLING
- TAILING SULPHUR DEPARTMENT



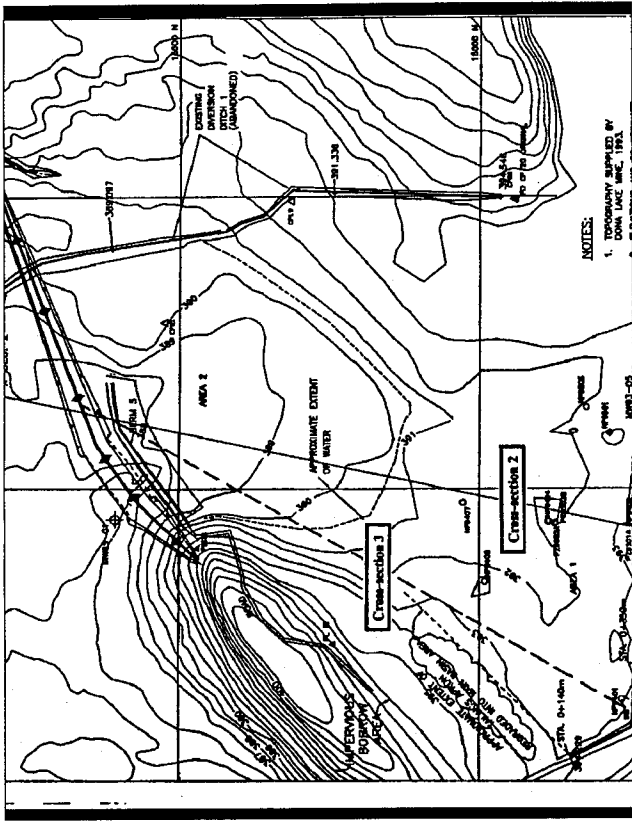
## FINDINGS OF MT. MILLIGAN ARD INVESTIGATIONS

- OVERBURDEN HAS NO POTENTIAL TO GENERATE ARD
- 60% OF WASTE ROCK NON-ACID GENERATING
- WORST CASE WASTE ROCK HAS NOT GENERATED ACID IN 3.8 YEARS IN LAB
- SCAVENGER TAILING NON-ACID GENERATING
- CLEANER TAILING GENERATED ARD IN 2.6 YEARS IN LAB
- CARBONATES AND SILICATES NEUTRALIZE ACID
- COARSE SULPHIDES BECOME COATED IN LAB EXPERIMENTS



## MT. MILLIGAN ARD PREVENTION PLAN

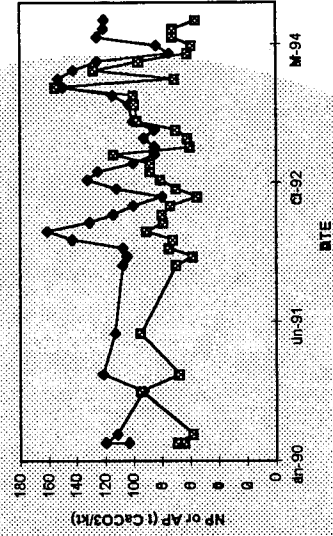
- CLEANER TAILING TO BE STORED IN SEPARATE CELL AND KEPT SATURATED
- POTENTIALLY ACID GENERATING WASTE ROCK TO BE SEPARATED AND STORED IN DESIGNATED LOCATION
- POSSIBLE BLENDING OF WASTE ROCK
- LAST 4 YEARS OF WASTE ROCK TO BE BACKFILLED INTO PIT



## ARD PREVENTION PLAN

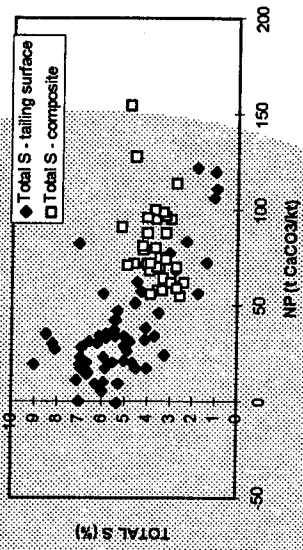
- CONSTRUCT WATER RETAINING DAM ON DOWNSTREAM END
- PARTIALLY FLOOD TAILING AND RAISE WATER TABLE
- LOWER TAILING ELEVATION AT UPPER BERM BY MOVING TAILING CLOSER TO THE POND

## TEMPORAL VARIATION IN TAILING ABA

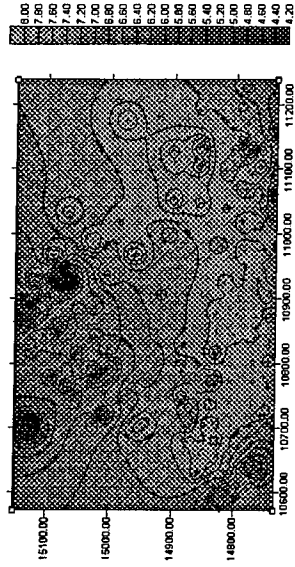




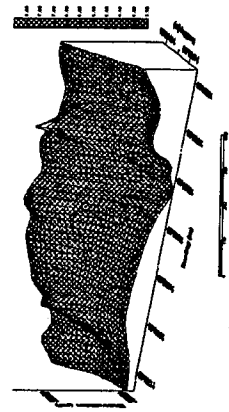
# RAW TAILS AND POND ABA



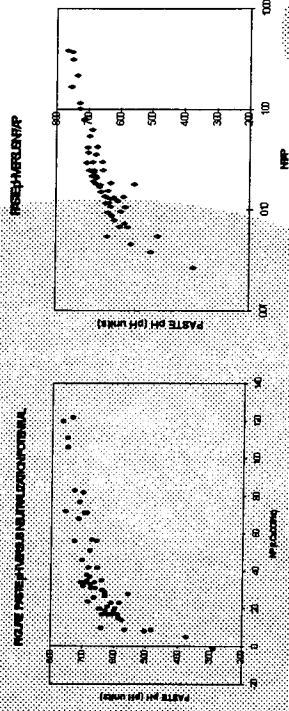
# PASTE pH OF SURFACE TAILING



# VARIATION OF PASTE pH WITH ELEVATION



# VARIATION IN PASTE pH AND NP & NP/AP



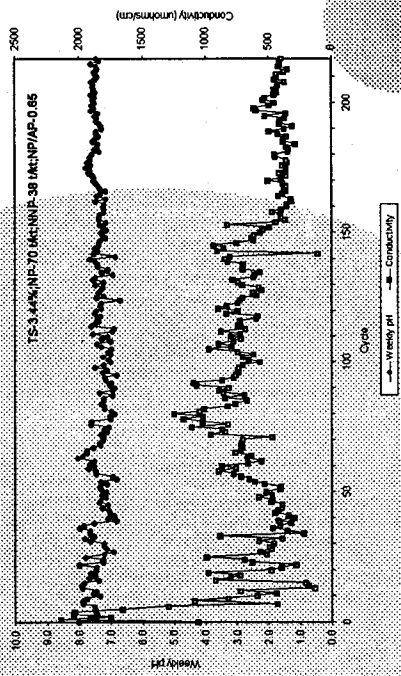
# RESULTS OF SUCTION LYSIMETERS

Parameter SL 95-02 SL 95-04

Parameter	SL 95-02	SL 95-04
<b>General:</b>		
pH	6.79	-
Alkalinity	26.9	-
Sulphate	2600	-
<b>Metals:</b>		
Al	<0.20	<0.20
As	<0.20	<0.20
Cd	<0.010	<0.010
Cu	0.013	<0.010
Fe	0.378	<0.030
Pb	<0.050	<0.051
Ni	0.13	<0.020
Zn	0.065	0.014

# STATUS OF KINETIC TEST

Weekly pH & Conductivity vs Cycle



# RESULTS OF ARD MODELLING

FIGURE 1 PREDICTED pH IN RESPONSE TO DYES 1

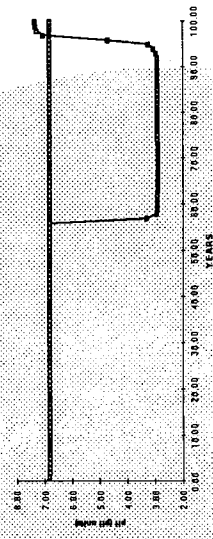
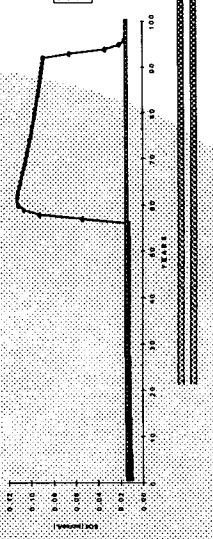
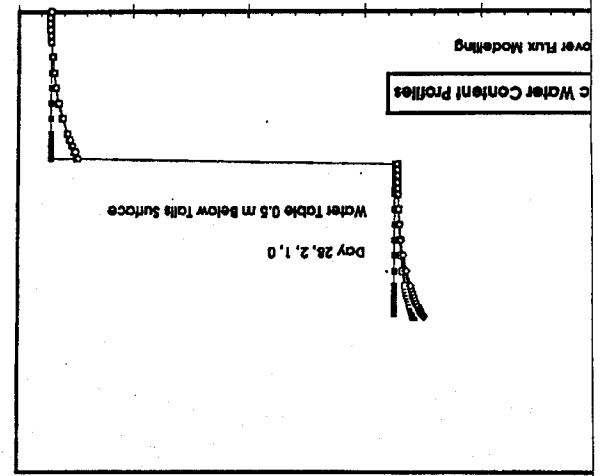


FIGURE 2 PREDICTED pH IN RESPONSE TO DYES 2



# Water Content Profiles



## MODIFIED ARD PREVENTION PLAN

- CONTINUE TO FLOOD LOWER PART OF IMPOUNDMENT
- MOVE MORE TAILING FROM "APRON" (POSSIBLY AFTER MIXING LIMESTONE)
- FURTHER REDUCE "HIGH SPOTS" IN TAILING
- CONSIDER ORGANIC COVER FOR SOME PORTIONS OF TAILING SURFACE
- CONTINUE TO MONITOR ABA AND WATER CONTENT PARAMETERS

## MODELS FOR ARD PREDICTION

- EMPIRICAL MODELS
  - WATER CONTAMINANT BALANCE MODELS
  - GEOSTATISTICAL MODELS & SCHEDULING
- QUASI-MECHANISTIC MODELS
  - WATAIL
- MECHANISTIC MODELS
  - GEOCHEMICAL MODELS
  - SOIL COVER & SEEP/W
  - RATAP

## WATER/CONTAMINANT BALANCE MODELS

- EMPIRICAL MODELS CALIBRATED TO FIELD CONDITIONS
- ASSUME INFILTRATION RATES
- CALCULATED AREAS OF EXPOSED MATERIAL
- USE CONCENTRATIONS FROM FIELD DATA & SOMETIMES KINETIC DATA (RATES)
- CONSIDER PRECIPITATION PATTERNS (USUALLY MONTHLY)

## LIME REQUIREMENTS FROM MODEL

